2012

Conversion to perennial vegetation: Quantifying soil water regime, aeration, and implications for enhancing soil resilience to climate change

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Conversion to perennial vegetation: Quantifying soil water regime, aeration, and implications for enhancing soil resilience to climate change

Abstract
Iowa was once awash with native prairie vegetation, and now it is covered with annual crops. This project looked at the different effects these two systems have on Iowa's landscape and natural resource base.

Keywords
Agronomy, Conservation practices, Soils and agronomy, Water quality quantity and management

Disciplines
Agronomy and Crop Sciences | Natural Resources and Conservation | Soil Science | Water Resource Management

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Competitive Grant Report E2009-18

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Abstract: Iowa was once awash with native prairie vegetation, and now it is covered with annual crops. This project looked at the different effects these two systems have on Iowa's landscape and natural resource base.

Q What are the environmental impacts of corn- and prairie-based systems on soil, water and air?

A Results indicate that relative to corn systems, prairie systems reduced soil compaction, decreased soil water drainage, decreased nitrate leaching, decreased soil nitrous oxide emissions, and increased soil carbon dioxide emissions. Overall, the prairie systems had favorable environmental impacts relative to corn systems.

ECOLOGY

Background

The project was designed to provide a quantitative, side-by-side comparison of corn- and perennial-based cropping systems by analyzing soil ecosystem processes. The overall objectives were to:

- provide comprehensive, long-term comparisons of a range of contrasting biomass feedstock production systems to continuously measure the volumes and nitrate concentrations of soil water drainage and the soil atmosphere concentrations of carbon dioxide, CO2, and oxygen, O2, in reconstructed prairie and cropping systems managed for biofuel production;
- complement these measurements with periodic measurements of the two most significant greenhouse gas (CO2 and nitrous oxide N2O) fluxes, management zone bulk densities, air permeability, soil aggregate stability, and plant rooting characteristics; and
- utilize the data to construct a user-friendly, modular computer simulation model of soil ecosystem responses to changing land use and potential climate change scenarios suitable for federal, state, and local agency personnel.

Leopold Center support helped to expand ongoing research at the Comparison of Biofuel Systems (COBS) site developed by Iowa State University. The COBS plots were established in 2008 to look at different ways of producing feedstock for grain-based biofuel and for biofuel made from cellulosic materials such as corn stover or prairie stover (aboveground plant material).

Approach and methods

The relatively large-scale experiment (24 plots, each 27 m x 61 m) compared the following cropping systems: continuous corn grown for grain and stover removal with and without a rye cover crop; reconstructed, multi-species prairie grown for whole-plant, aboveground harvest with and without fertilizer; and a conventional corn-soybean grain system, which is used as a baseline treatment for comparison.

For this project, investigators compared the impacts of perennial feedstock produc-

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Budget:
$25,210 for year one
$26, 216 for year two
$31,626 for year three

tion strategies vs. corn production on water quantity and water quality (nitrate flux) by quantifying total subsurface drainage and nutrient export with the subsurface drainage. Flow-weighted drainage samples were collected as dictated by precipitation and drainage patterns, with sampling occurring at least twice a week during high-flow periods. Subsurface drainage volume was measured continuously with data-logging equipment and cumulative volume measurements also were recorded. Water samples were analyzed for nitrate presence. Flow volumes and nitrate concentrations were used to compute loads exiting each plot. The team measured fluxes of the greenhouse gases, CO2 (2009-20011) and N2O (2011) from the treatment plots at weekly intervals throughout the growing seasons.

Soil cores for bulk density and root distribution were collected annually. Soil temperature and water content were measured from 5 to 50 cm down throughout the year.

Results and discussion

Multispecies prairies fertilized with a moderate rate of N provided about 70 percent of the aboveground biomass of corn that had been fertilized at substantially higher N rates. Prairie mixtures not receiving N fertilizer produced about 70 percent of the aboveground biomass of the fertilized prairie mixtures and about 50 percent of the biomass of corn. Prairie plots had approximately eight to twelve times more roots and, correspondingly eight to twelve times as much root carbon as the corn plots. Unfertilized prairie plots produced more root biomass than fertilized prairie plots, despite having lower above-ground biomass.

In 2010 and 2011, the volume of water carried by the tile lines from the perennial treatments was less than that of the annual cropping systems. When nitrate-N concentrations were coupled with the drainage volumes, the cumulative loss of nitrate N over the 2010 growing season was 20-30 times less in the perennial systems than in water draining from the annual cropping system plots. In 2011, nitrate N loss was about five to 20 times less in the perennial plots than in the annually cropped plots.

During the growing seasons, CO2 emissions from the cropping systems plots varied from one another primarily in the early and middle parts of the growing season. In general, the prairie systems emitted more CO2 than the other treatments, and the non-fertilized prairie system emitted the most CO2. Preliminary measurements of nitrous oxide (N2O) flux from the treatments shows that N2O fluxes, integrated from early April through the end of July 2011, ranged from 100 to 1860 g N2O per hectare. The cumulative N2O emissions were lower in the prairie and soybean treatments than in corn. Corn, continuous corn, and continuous corn with winter cover crop produced 19, 16, and 12 times as much N2O as the unfertilized prairie treatment. In contrast, soybeans and fertilized prairie produced only two times as much N2O as the unfertilized prairie treatment. Even when fertilized, cumulative N2O emissions from the prairie system were significantly less than those from corn systems.

The proposed scope of the model was found to be beyond the reach of the available project resources. Nonetheless, good progress was made and a proof-in-concept of the modeling approach was demonstrated. Some key findings were:

Monitoring of soil carbon dioxide fluxes.

- Water drainage volumes and nutrient fluxes were less in the prairie systems than in the corn systems.
- CO2 fluxes were less in the corn than in the prairie systems, however, N2O fluxes were larger in the corn than in the prairie systems.
- A preliminary model characterizing cropping system impacts on soil has been developed, however, further work must be done in order to make the model an effective statewide tool.
- Additional research is needed to verify the differences in N2O fluxes for the cropping systems, and to perform a comprehensive water balance on the cropping systems. It is unclear why the prairie treatments had much smaller drainage volumes compared with the corn treatments. There must be a comprehensive investigation of various water balance components to determine quantitative water fractioning in the cropping systems.

Conclusions

Quantifying the impact of biofuel crops on soil, water and air qualities is critical information for use by policy makers and agency personnel to complete a comprehensive environmental assessment of biofuel cropping systems. Soil physical properties, N2O effluxes, soil root densities, and tile drainage loads all appear to be beneficially enhanced under prairie systems relative to corn in traditional corn-soybean rotations and continuous corn systems with and without cover crop. Work on a model/decision support tool was slower than anticipated.

Nonetheless, good progress was made and a proof-in-concept of the approach has been demonstrated. To finish the model and make it an effective statewide tool ideally would include CT-scans of major Iowa soils under both row-crop and prairie vegetation. Further research on the benefits of perennial biofuel cropping systems on ecosystem assets such as water use and water balance components is needed to articulate the full impact of land use changes from annual row crops to perennial cropping systems on soil, water and air resources.

Impact of results

Findings from this study support the Ecology Initiative's mission of developing more ecologically friendly production systems. Perennial crops (such as mixed prairie) grown on marginal cropland can help diversify the economic base of rural areas, create an annual income source, and have positive conservation benefits for soil, water and air quality. Relationships developed during this study support stronger partnerships between the traditional agricultural and ecological communities. These relationships will assist landowners who are considering the conversion of degraded or marginal cropland to perennial crops or reconstructed prairies.

Education and outreach

No journal article publications from this study have yet been completed. However, several articles are being prepared for submission to scientific journals including *Water Resources Research, Journal of Environmental Quality, Soil Science Society of America Journal,* and *Soil Science*. Six scientific presentations based on the results of this project were given at 2010-2012 meetings of the American Society of Agronomy or Soil Science Society of America. Field day presentations were made to the Iowa Corn Promotion Board and Iowa Corn Growers Association, the Agronomy Freshman Field Trip in 2011, and the Middle School Science Teachers Environmental Research Experience Program in 2010.

Leveraged funds

The initial investment for this project (from ConocoPhillips Company and from the ISU College of Agriculture and Life Sciences) allowed identification of the field site, plot layouts, seeding of crops, emplacement of tile drains in and between plots, and installation of water sampling equipment, soil sensors, data-loggers and weather-monitoring equipment. Additionally, the COBS investigators successfully obtained funding from the USDA, the Plant Sciences Institute, and the Iowa Water Center. The LCSA investment was $82,852 and the leveraged funding was approximately $1,050,000.

Fertilized prairie next to corn crop.

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